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Newfoundland and Labrador Region
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STOCK ASSESSMENT OF NORTHERN (2J3KL) COD IN 2011

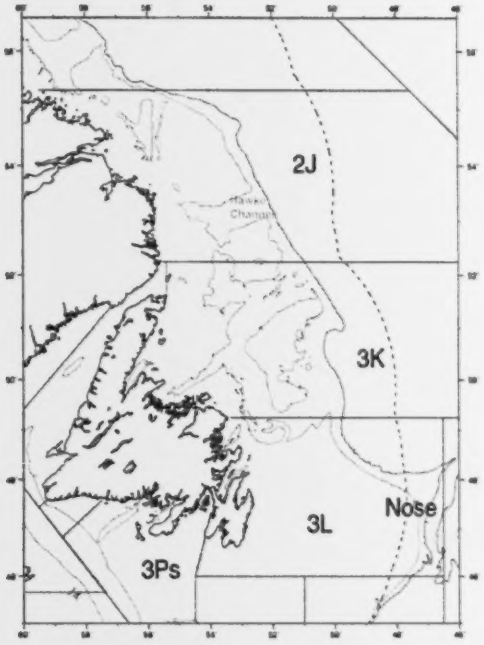

Figure 1: Stock area of northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context :

The biomass (of ages 3 and older) of the northern cod (Gadus morhua) stock off southern Labrador and eastern Newfoundland (NAFO Divisions 2J3KL; Fig. 1) was about 3 million t in the early 1960s. Fishing intensity increased greatly in the 1960s as non-Canadian fleets exploited dense offshore over-wintering aggregations. The stock collapsed to about 0.5 million t by the late 1970s. After extension of jurisdiction in 1977, the stock recovered partially to just over 1 million t in the mid-1980s, but it declined again during the late 1980s and collapsed to an extremely low level by the early to mid-1990s. A moratorium on directed commercial fishing was declared in 1992.

Historically, many cod migrated from over-wintering areas offshore to feeding areas inshore, where they were exploited by the traditional inshore fixed-gear fishery. By the mid-1990s it was apparent that these offshore populations were barely detectable. At the same time, it was recognized that there were aggregations of cod in the inshore in Div. 3L and southern Div. 3K. These inshore populations appeared to be more productive during the 1990s than populations in the offshore. A small fishery directed at these inshore populations was introduced in 1998. Catch rates declined and the directed commercial fishery was closed in 2003. A food/recreational fishery, which had been open for several years, was also closed. Catches during 2003-05 were limited mainly to bycatch in the winter flounder (blackback) fishery.

A directed stewardship fishery and recreational fisheries were re-opened in the inshore in 2006 and continued in 2007-10. This stock is assessed annually. At a framework meeting in November 2010, a conservation limit reference point (LRP) was established for Northern cod against which current status

and trends can be compared for advice purposes; however, no timelines for rebuilding have been identified by management. The present assessment is the result of a request for science advice from the Fisheries and Aquaculture Management (FAM) Branch (Newfoundland and Labrador Region). The main objectives were to evaluate the status of the stock and provide scientific advice in accordance with the Sustainable Fisheries Framework.

The current evaluation of the stock was conducted through a regional assessment process (RAP). The meeting was held 22-23rd March 2011 in St. John's (NL). Participants included DFO Scientists, fisheries managers, and officials from provincial governments, non-government organizations, fishing industry members, and academia.

SUMMARY

Catch

- Total catch in 2010 is uncertain. Accurate catch information is needed to evaluate the impact of fishery removals on the stock status.
- Reported landings in 2010 were 2,902 t. This included 2,649 t in the stewardship fishery, 209 t in the sentinel surveys, and 44 t taken as by-catch, but excludes recreational fishery removals.
- There are no direct estimates of recreational landings for 2010. However, analysis of tag returns suggests that removals of commercial size fish from recreational fisheries during 2010 were 56% of the stewardship fishery removals. In addition, there was evidence of widespread discarding of small fish in the recreational fishery in 2009 and 2010.

Offshore

- Based on a cohort analysis of the DFO autumn RV survey data, the recent increasing trends in total biomass and spawning stock biomass (SSB) have not continued. Total biomass increased during 2004 to 2009 but was unchanged in 2010. SSB increased from 2004 to 2008, but has since been unchanged.
- Total mortality declined substantially during 2003-05 and remained low to 2007 (< 20%). This has been an important factor in the recent increase in total biomass and SSB. However, total mortality has increased to approximately 40% in 2009 and 2010, and if this level of total mortality continues, prospects for further stock growth are diminished.
- The exploitation rate of offshore cod in the inshore based on tag returns was low and ranged between 3% and 6% during 2008-10.
- Recruitment has shown marginal improvement (2005 to 2007 year-classes); however, recruitment is still much lower than was observed in the 1980s.

Inshore

- Sentinel catch rates in the northern area did not increase in 2010 and were near the 1995-2010 northern area average. Catches in this area depend on seasonal immigration of fish from offshore regions, including 2J where offshore biomass remains low. Sentinel and commercial catch rates are lower in the northern area than those in the central area.
- Sentinel catch rates in the central area did not increase in 2010 but remained above the 1995-2010 central area average. Catches in this area depend on resident inshore components and seasonal migrants from the offshore.
- Sentinel catch rates in the southern area declined in 2010 and were below the 1995-2010 southern area average. Catches in this area are partly dependent on seasonal immigration of fish from the offshore of 3KL, and from 3Ps where the stock has declined.
- During 2008-10, mean exploitation rates from tagging studies were low and ranged between 3% and 10% among inshore central and southern areas.
- Recent year-classes in the inshore have been poor relative to the 2000-02 year-classes.

Whole stock

- A conservation LRP has been established for Northern cod. Estimated SSB has been well below the LRP since the early 1990s. The estimate of 2010 SSB is 90% below the LRP.
- Current levels of removals have resulted in low exploitation rates and probably have had little impact on recent stock dynamics.
- At current levels of stock productivity (growth rates, recruitment, survival) the stock will not reach the LRP within the next five years.
- The application of the DFO fishery decision-making framework incorporating the precautionary approach would require catches in 2011 to be at the lowest possible level.

INTRODUCTION

History of the Fishery

Catches of northern cod increased during the 1960s to a peak of over 800,000 t in 1968, declined steadily to a low of 140,000 t in 1978, increased to about 240,000 t through much of the 1980s, and then declined rapidly in the early 1990s in advance of a moratorium on directed fishing in 1992 (Fig. 2).

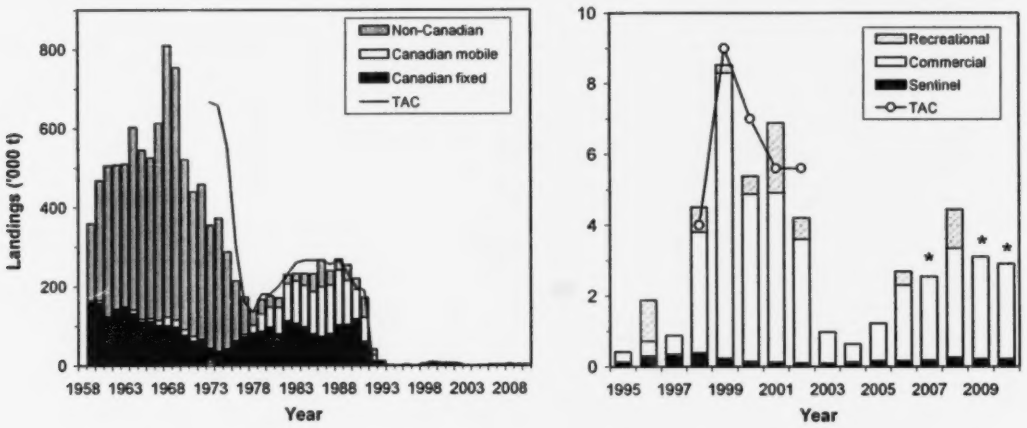

Figure 2: Total Allowable Catches (TACs) and landings (thousands of tons) in 1959-2010. The right panel is expanded to show trends from 1995 onwards. Asterisks indicate that recreational catches in 2007, 2009 and 2010 are uncertain and are not shown.

Landings during 1993-97 came from by-catches, food/recreational fisheries, and DFO-industry sentinel surveys that started in 1995. In addition, landings from 1998-2002 also came from a limited index/commercial inshore fishery restricted to fixed gear and small vessels (<65 ft). The directed commercial and recreational fisheries were closed in April 2003; most of the landings in 2003 came from an unusual mortality event in Smith Sound, Trinity Bay. During 2004 and 2005, substantial by-catches (>600 t) of cod were taken in the inshore, mostly in 3KL, in the winter flounder (blackback) fishery.

A stewardship fishery and a recreational fishery for cod were re-opened in 2006 and continued in 2007-10. Commercial fishers were permitted an allowance of 3,000 lb of cod per license holder in 2006, 2,500 lb in 2007, 3,250 lb in 2008, and 3,750 lb in 2009 and 2010. Total catch in 2010 is uncertain. Reported landings in 2010 were 2,902 t. This included 2,649 t in the stewardship fishery, 209 t in the sentinel surveys, and 44 t taken as by-catch, but excluded recreational removals. There are no direct estimates of recreational landings for 2010. However, analysis of tag returns suggests that removals from recreational fisheries during 2010 were 56% of annual stewardship fishery removals. Mean lengths of cod sampled at the dock during the 2010 recreational fishery were higher than those sampled at sea in several areas, suggesting widespread discarding of small fish during the 2010 recreational fishery.

Estimates of commercial catch are also uncertain. Commercial fishers often report that commercial landings are underestimated. If the level is substantial then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

The Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) estimated that annual catch of cod by non-Canadian fleets outside the 200 nautical mile limit on the Nose of the Grand Bank (Div. 3L) during 2000-09 were 80 t or less (18 t for 2009).

Landings

Table 1: Reported landings by management year in NAFO Divs. 2J3KL (nearest thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	98	99	00/ 01	01/ 02	02/ 03	03-06 Avg.	06/ 07[1]	07/ 08[1,2]	08/ 09[1]	09/ 10[1,2]	10/ 11[1,2]
TAC	N/A	N/A	4	9	7	6	6	0	-	-	-	-	-
Can. Fixed	88	90	5	9	5	7	4	1	3	3	4	3	3
Can. Mobile	9	84	-	-	-	-	-	-	-	-	-	-	
Others	405	38	-	-	-	-	-	-	-	-	-	-	
Totals	502	212	5	9	5	7	4	1	3	3	4	3	3

[1] There was no TAC in the last five years, but fishers were permitted an allowance per license holder of 3,000 lb in 2006/07, 2,500 lb in 2007/08, 3,250 lb in 2008/09, and 3,750 lb in 2009/10 and 2010/11.
[2] Does not include estimates of Canadian recreational fisheries.

Species Biology

Cod off Labrador and eastern Newfoundland grow slowly compared with individuals in the eastern Atlantic and further south in the western Atlantic. Since the late 1980s females have been maturing at about age 5, which is younger than in previous years.

Historically much of the stock was highly migratory. They over-wintered near the edge of the continental shelf and migrated in spring/summer to shallow waters along the coast and onto the plateau of Grand Bank.

Small cod tend to feed on small crustaceans; medium-sized cod feed on larger crustaceans and small fish; and large cod feed on medium-sized fish and crabs. Capelin in particular has historically been an important part of the annual diet. Very small cod are eaten by squid, many species of groundfish, including larger cod, and some species of birds. Larger juveniles are eaten by larger groundfish, seals and other marine mammals. Large cod probably have few natural predators, but seals can prey upon them by belly-feeding.

Stock Structure

There is evidence that there are cod populations in the inshore that are functionally distinct from those in the offshore. Inshore populations are small relative to the populations that historically migrated into the inshore from the offshore during spring/summer.

Tagging studies revealed that during the late 1990s to the mid 2000s the inshore of 3KL was inhabited by at least two groups of cod: (1) a resident coastal group that inhabited an area from eastern Trinity Bay northward to western Notre Dame Bay (Fig. 3) and (2) a migrant group that over-wintered in inshore and offshore areas of 3Ps, moved into southern 3L during late spring and summer, and returned to 3Ps in the autumn. Tagging studies also indicated considerable movement of cod among Trinity Bay, Bonavista Bay and Notre Dame Bay.

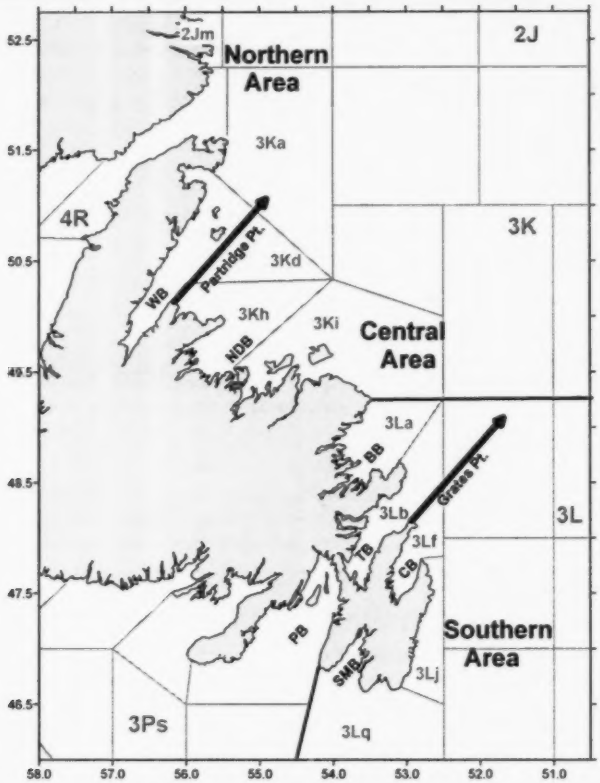

Figure 3: Eastern Newfoundland indicating the locations of the inshore northern, inshore central and inshore southern areas. Major bays are indicated: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB), and St. Mary's Bay (SMB); Placentia Bay (PB) is in Subdiv. 3Ps. Grey lines delimit boundaries of statistical unit areas (i.e. 3Ka, 3Kd, etc.) referred to in the text.

Some aspects of current stock structure require further study. Catch rates increased in sentinel surveys in 2J and northern 3K in 2005 (see below), but the origin of the fish that generated these higher catch rates is uncertain. The extent of migration between the inshore and offshore of 2J3KL during recent years is not well understood, but tagging results indicate that the historical shoreward seasonal migration pattern of the pre-moratorium period did occur during 2008-10. The offshore biomass of cod in 2J3KL is low but increased during 2003-08; the contribution of offshore cod to the inshore biomass during summer may have increased during this period.

Ecosystem information

During the late 1980s and early 1990s the fish community in the Newfoundland and Labrador large marine ecosystem collapsed. This collapse was more dramatic in the northern regions and involved commercial and non-commercial species. During 2003 to 2007 there was an increasing trend in the fish biomass in 2J3K and 3LNO; some components of the fish community (e.g. piscivores such as Atlantic Cod, Greenland Halibut, and Atlantic Halibut) and large benthivores (e.g. American Plaice) showed some positive signals, but still remain at a significantly lower level in comparison to the pre-collapse period. These were the first significant changes observed in the fish component of ecosystem structure since the collapse. However, the most

recent ecosystem information is less optimistic and overall biomass level of the fish community did not continue increasing, remaining at the level reached in 2007-08.

Oceanography

The marine environment off Labrador and eastern Newfoundland experienced considerable variability since the start of standardized measurements in the mid-1940s. A general warming phase reached its maximum by the mid-1960s. Beginning in the early 1970s there was a general downward trend in ocean temperatures, with particularly cold periods in the early 1970s, early to mid-1980s and early 1990s. Ocean temperatures have been above normal for the past decade, reaching record highs in 2006 before declining to more normal values in 2007-09. In 2010, temperature conditions in many areas increased to 2006 values.

It is anticipated that cod in this area may be more productive when water temperatures are toward the warm end of the regional norm. Cod somatic growth was showing an increasing trend in 3KL when temperatures were approaching the peak of 2006, but this trend has reversed.

Predators

The harp seal population has been increasing slowly for several years and is estimated to be approximately 9 million animals in 2010 (G. Stenson, DFO, pers. comm.). Some populations of cetaceans have also been increasing. Collectively marine mammals consume huge quantities of prey and have the potential to exert a strong influence on ecosystem dynamics including cod populations, directly through predation as well as indirectly by consuming key prey such as Capelin and shrimp. There is a high level of uncertainty surrounding the impact of marine mammal consumption on cod dynamics.

The quantity of cod estimated to have been consumed by harp seals has increased since the late 1980s due, primarily, to increased occurrence of Atlantic cod in near-shore diet samples. However, estimates of total Atlantic cod consumption by harp seals are highly imprecise. Analyses presented in 2001 indicated that harp seals may have an impact on the recovery of 2J3KL cod; however, ongoing analysis from a simple biomass-based model exploring the impact of harp seals on 2J3KL cod under a wide range of consumption estimates suggests that seal predation is not a significant factor in the lack of recovery to date. This model also indicates that Capelin availability and fishing on cod have had a strong influence on the population dynamics of 2J3KL cod.

Prey

Both Capelin and *Pandalus* shrimp appear as main prey for cod based on analysis of cod stomachs sampled during Research Vessel (RV) Fall surveys. During the 1980s and early 1990s Capelin was the main prey in the fall diet of cod. In recent years, *Pandalus* shrimp has become a key prey, increasing its contribution to the diet of cod over time. This increasing trend started in the late 1980s, but became more important in the mid 1990s; this coincided with the increase of *Pandalus* shrimp in the environment. The RV biomass index of *Pandalus* shrimp increased significantly from the early 1990s until the mid 2000s, but has declined since 2006-07. In 2009 the RV biomass index for shrimp showed a sharp decline reaching levels similar to those observed in the mid 1990s, and appears to continue at that lower level in 2010. There is an indication of slightly lower biomass of shrimp in the stomachs of cod in 2J3KL in 2009.

An index of offshore Capelin biomass, based on a spring 3L hydro-acoustic survey, indicates that Capelin biomass was high in the 1980s, but dropped dramatically in the early 1990s and has remained low. This general pattern of change in Capelin availability appears to be reflected in the cod diet. Although the 3L hydro-acoustic survey indicated an increase in offshore Capelin biomass in 2007-09 relative to levels during the 1990s and early 2000s, the biomass was still far below what it was in the 1980s; nonetheless, the timing of this improvement in Capelin coincided with recent increases observed in biomass of cod in portions of the offshore. In 2010 this index showed a sharp decrease in Capelin biomass, and is the lowest estimate in the entire survey series.

Both shrimp and Capelin are important prey for cod; Capelin are at low levels and shrimp are declining. A combined low availability of two major forage species in the system could compromise the potential for recovery of cod in particular, and the groundfish community in general.

ASSESSMENT

In this assessment, a cohort analysis of autumn RV catch rate data was used to infer trends in the status of cod in the offshore. For inshore and offshore areas, trends in indices and harvest rates inferred from tagging studies were also examined. Catch rates of ages 3 and 4 from sentinel surveys were modeled to develop a recruitment index. Total landings are uncertain and catch-based analytical models such as sequential population analysis (SPA) could not be used.

Due to differences in the dynamics of offshore and inshore populations since the mid-1990s, information is provided for the offshore and inshore separately.

The main sources of data for this assessment are as follows, for the offshore and inshore respectively. For the offshore, indices of abundance, biomass and other biological characteristics are obtained from multi-species RV bottom-trawl surveys conducted by Fisheries and Oceans Canada (DFO) in the whole of Div. 2J3KL during the autumn and in Div. 3L during the spring. Information on recruitment and total mortality is obtained from analysis of catch rate at age in the autumn surveys. Recaptures of conventionally tagged cod and detections of acoustically tagged cod released offshore in February-March 2007 and March 2008 were used to estimate exploitation rates and investigate migration patterns.

For the inshore, indices of abundance are provided by DFO-Industry fixed-gear sentinel surveys. Fixed-gear sentinel surveys are conducted by two traditional gears; gillnets of 5½ inch mesh and line-trawls, and a non-traditional 3¼ inch mesh gillnet, which is intended to provide information on young fish. Logbooks from vessels less than 35 feet for post-moratorium fisheries were also examined to investigate area-specific trends in catch rates. Tagging studies initiated in 1997 and continued during 2006-10 provide information on exploitation, distribution and migration. Hydro-acoustic surveys were conducted in Smith Sound in winter and spring 1997-2004 and 2006-11. An annual telephone survey of fish harvesters' observations is conducted by the Fish, Food and Allied Workers (FFAW) Union. Information on the relative abundance of young cod (Ages 0 and 1) is provided by beach seine studies in Newman Sound, Bonavista Bay (Fig 3). Information on the size and age composition of the catch is obtained from lengths and otoliths collected from cod sampled at ports and at sea. A DFO-Industry bottom-trawl survey using small (<65 ft) commercial vessels was conducted annually during July-August 2006-10. This inshore trawl survey provides information on the relative abundance, age composition and distribution of cod inhabiting the coastal and nearshore area of 2J3KL.

Stock Trends – Offshore

Bottom-trawl surveys

The abundance and biomass indices from the autumn RV surveys during 2008-10 are 8% and 9%, respectively, of the average during the 1980s (Figs. 4 and 5). The abundance index increased during 2003-09; the biomass index increased during 2003-08, but the increasing trend has not persisted and the 2010 values for both indices are lower than the 2009 values.

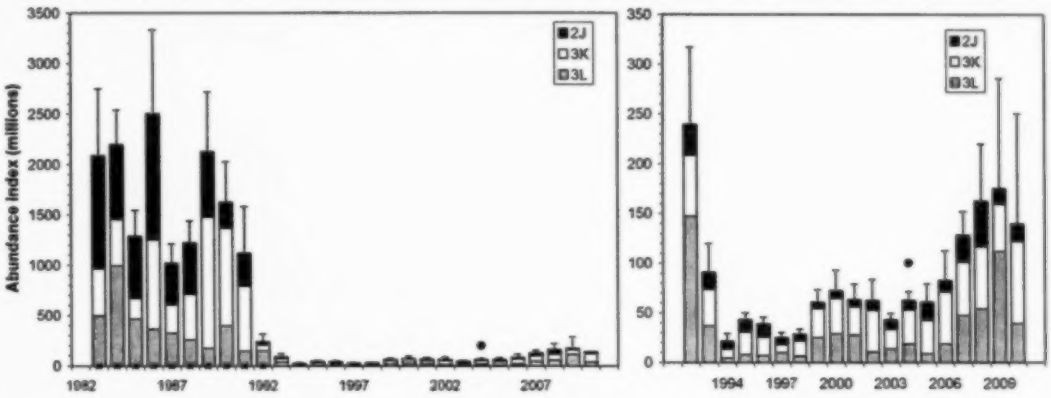

Figure 4: Offshore abundance index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

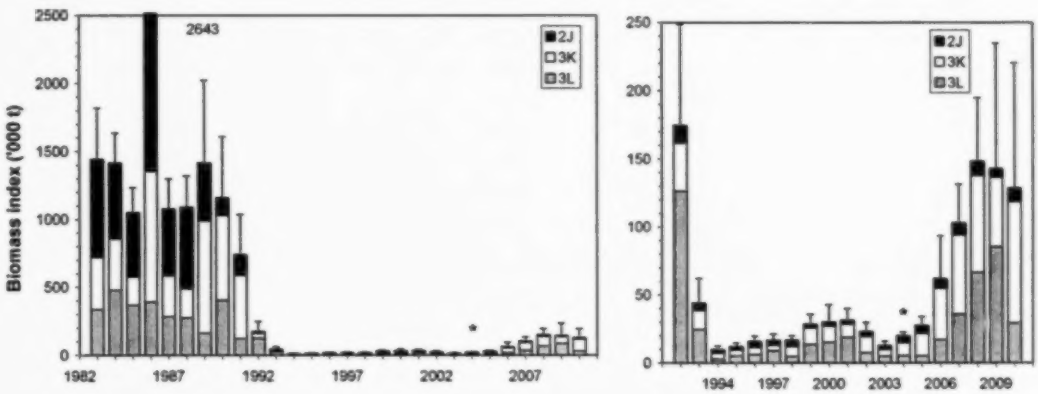

Figure 5: Offshore biomass index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

The 2010 survey abundance index and biomass index values are 139 million and 129,000 t. The autumn 2010 offshore RV survey abundance and biomass is concentrated (64% and 83% of totals, respectively) adjacent to the 3K/3L boundary. This region encompasses only 14% of the total surveyed offshore area of 2J3KL, and in the 1980's contained <20% of survey abundance and biomass. There has been no increase in abundance or biomass in 2J.

In 2004, the autumn survey did not complete a portion of northeastern 3L that includes seven strata where cod have often been found at higher density in previous surveys. The survey estimate for 2004 is probably low.

Some of the autumn RV surveys have extended well beyond their normal time and into the winter because of vessel problems. In addition, in some years coverage in some regions was sparse. These changes add uncertainty to survey estimates of mortality rates, abundance, and biomass.

The SSB index from the fall RV survey was low for several years after the 1992 moratorium, but increased during 2005-08 (Fig. 6). The increasing trend has not continued and the 2009 and 2010 values are both lower than the 2008 value. The SSB index during 2008-10 is 11% of the average in the 1980s.

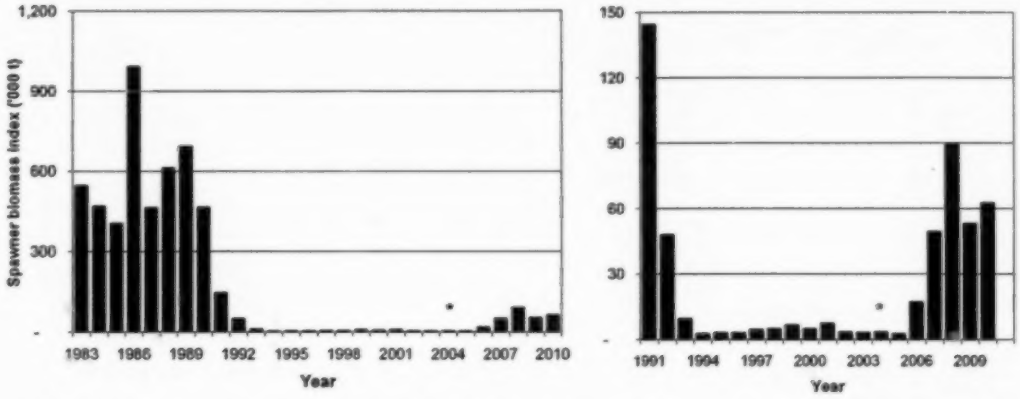

Figure 6: Offshore spawning stock biomass index from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1991 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

Information on recruitment and mortality is derived from mean catch rate at age during the autumn RV surveys.

Year-class strength in the offshore in the 1990s and 2000s has been poor compared to the 1980s. The number of young fish (ages 2 and 3) in the offshore survey in the 1990s and 2000s has consistently been much lower than during the 1980s (Fig. 7).

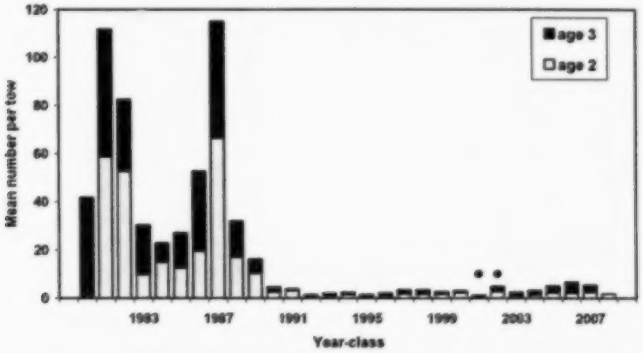

Figure 7: Abundance of the 1980-2008 year-classes at age 2 and age 3 in the offshore of 2J3KL from the autumn RV surveys. Asterisks indicate partial estimates for the 2002 year-class at age 2 and the 2001 year-class at age 3 due to incomplete survey coverage of 3L in 2004.

The total mortality rate (*Z*) (ages 4-6) was low in the 1980s, but was at a high level (*Z*>0.6, i.e. >45% per yr) from the early 1990s to the mid-2000s, with peaks during the early 1990s and early 2000s (Fig. 8). This high level of mortality has been a major impediment to stock recovery. Total mortality declined substantially during 2003-06, resulting in an expansion in the age composition, and this has been an important factor in the recent increase in total biomass and SSB. The *Z* in 2008-10 averaged 0.48, which corresponds to 38% mortality per year, but the 2010 value is close to the time-series average.

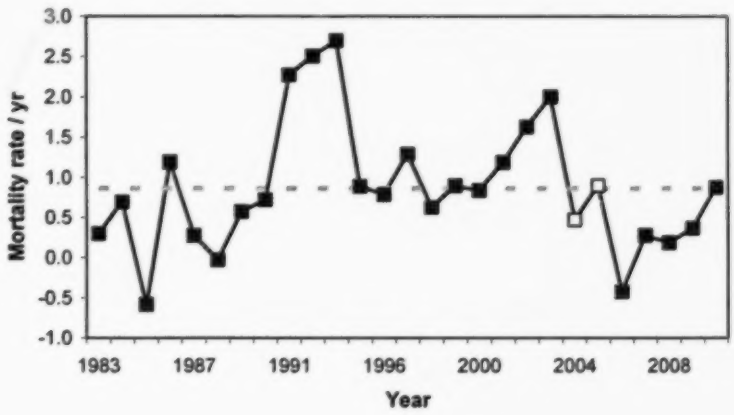

Figure 8: Total mortality rate (Z) of cod aged 4-6 calculated using data from the autumn RV surveys in the offshore of 2J3KL. For example, the value in 1996 is the mortality experienced by the 1991-1989 year-classes from ages 4-6 in 1995 to ages 5-7 in 1996. The dashed line is the time-series average (Z=0.87 which corresponds to 58% mortality per year). Open symbols indicate estimates based on an incomplete survey in 2004.

The above information on trends in abundance/biomass, recruitment and mortality are based on analysis of raw catch rate data from the DFO autumn RV surveys. The data (ages 2-12, 1983-2010, excluding 2004) have also been subjected to a more comprehensive cohort analysis which produces relative estimates of stock size. This analysis indicates that the recent increasing trends in total biomass and SSB have not continued (Fig. 9, lower panels). Total

biomass increased during 2004 to 2009 but was unchanged in 2010. SSB increased from 2004 to 2008, but has since been unchanged. The 2004 RV survey was excluded in this analysis due to incomplete survey coverage.

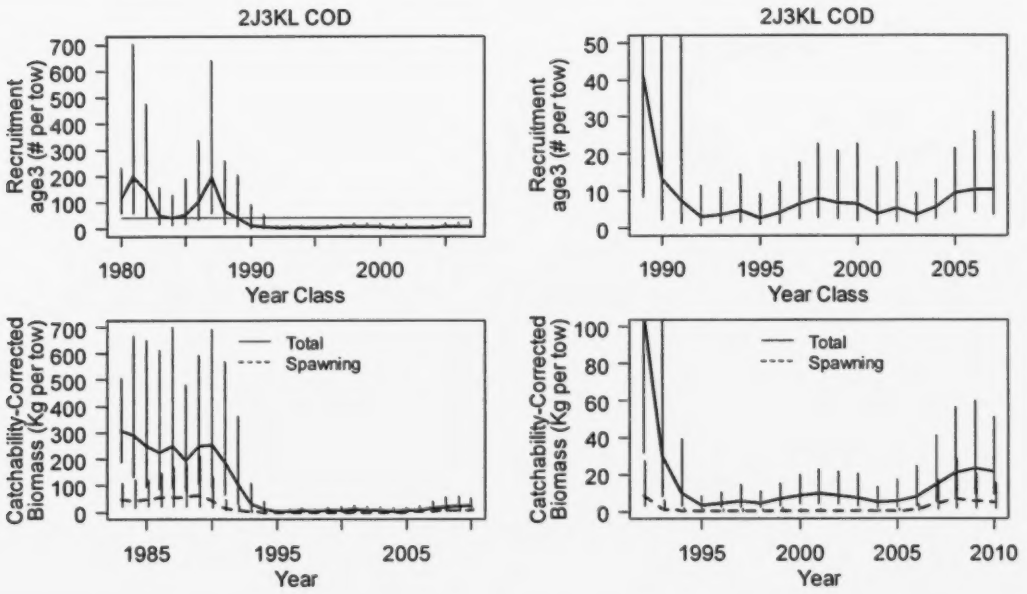

Figure 9. Trends in recruitment (age 3, upper panels) and biomass (ages 2-8) and SSB (lower panels, dashed line) estimated from cohort analysis of DFO survey data. Error bars are 95% confidence intervals. Horizontal lines indicate time-series average. The right panels show the recent time period with the y-axis re-scaled.

Cohort analysis indicates that the relative strength of all year classes produced since 1989 are below the time series average (Fig. 9, upper left panel). Recruitment has shown marginal improvement (2005 to 2007 year-classes, Fig. 9, upper right panel); however, recruitment is still much lower than was observed in the 1980s. The estimates for the most recent year classes are based on few data and are more uncertain.

A conservation LRP has been established for Northern cod (DFO, 2010). Estimated SSB has been well below the LRP since the early 1990s. The estimate of 2010 SSB is 90% below the LRP (Fig. 10).

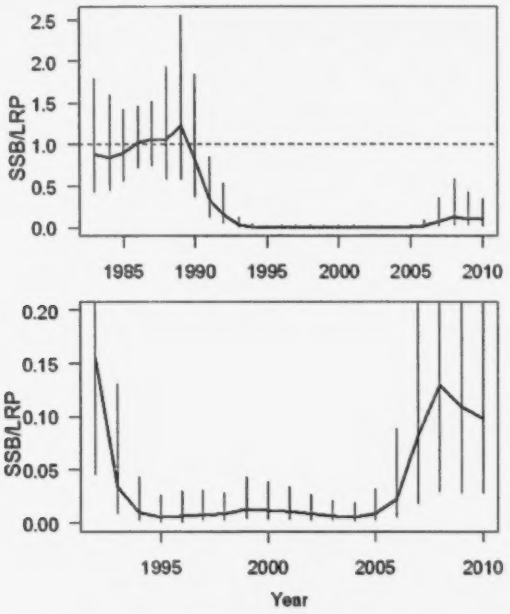

Figure 10. Trends in SSB relative to the LRP. The upper panel shows the full time series (1983-2010) and the lower panel the more recent (1992-2010) period. Error bars are 95% confidence intervals.

Estimates of *Z* from the cohort analysis indicate that the annual instantaneous rate of mortality increased during 1989-93, then declined and remained stable (*Z*~0.5, i.e. ~38% per year) during 1994-2000 (Fig. 11). Total mortality declined substantially during 2003-05 and remained low (*Z*<0.2, i.e. <18% per year) to 2007. This low *Z* has been an important factor in the recent increase in total biomass and SSB. However, total mortality increased in 2009 and 2010 (*Z*~0.5, i.e. ~38% per year), and if this level of total mortality continues, prospects for further stock growth are diminished.

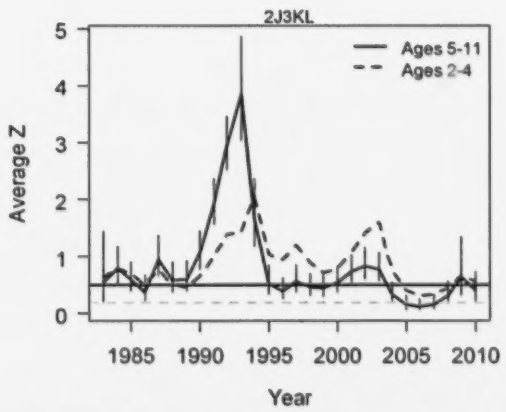

Figure 11: Z for two age groups of cod estimated from cohort analysis of DFO survey data. The horizontal lines indicate values of Z=0.5 (solid line) and Z=0.2(grey dashed line) which correspond to annual mortality rates of 39% and 18%, respectively. Error bars are 95% confidence intervals.

Offshore tagging

Offshore cod were captured and released with conventional and acoustic tags in deep water (> 330 m) on the outer edge of the continental shelf in Div. 3K during February-March 2007 and March 2008.

In the summer and fall of 2008-10, offshore tagged cod were recaptured inshore in the recreational and stewardship fisheries; recaptures were widely distributed throughout 3K and 3L as far south as Petty Harbour (3Lj). Offshore cod with acoustic tags were also detected on receiver arrays in nearshore areas of 3KL during 2008, 2009 and 2010, and >25% of those released in 2008 have now been detected inshore. These results indicate a substantial portion of cod from the offshore migrated to the inshore of 3KL during summer 2008-10, rendering them vulnerable to inshore fisheries. The exploitation rate of offshore cod in the inshore, based on tag returns, ranged between 3% and 6% during 2008-10.

Biological Information (Offshore)

The information in this section comes from sampling during the autumn offshore RV surveys.

Growth

Length-at-age and weight-at-age have improved since the low values of the early 1990s and were at or above average in Div. 2J and 3K but below average in 3L in 2010. Overall, for Divs. 2J3KL, weight-at-age in 2010 was average.

Condition

Condition of cod, as measured using information on length and gutted weight (relative condition), and length and liver weight (relative liver condition), increased in all Divisions in 2010 after declining in 2009. In Div. 2J and 3K relative condition was higher in 2010 than in most years, while relative condition was similar to most years in Div. 3L in 2010. Relative liver condition was significantly lower in 2009 than in 2008 or 2007 in all three divisions. In 2010 relative liver condition increased in all divisions but remains below the level of 2007 and 2008 in Div. 3K and 3L.

Maturity

The proportion of female cod that are mature at young ages has increased over time particularly among cohorts produced from the late 1980s onward. For example, the percentage of age 6 cod that are mature averaged about 50% in the 1980's, but has increased to about 80% since the early 1990s. Values for age-at-maturity among recent cohorts (2004-06) are more uncertain. Males generally mature about one year younger than females and show a similar trend over time. The reasons for the change towards earlier age-at-maturity are not fully understood. The change may have a genetic component and partly be associated with high levels of mortality and low stock size.

The most recent information on cod growth rates and condition indicate that these aspects of stock productivity are near average values; age at maturation remains low. These components of stock productivity are generally below the levels observed in the early 1980s when biomass and harvests were much larger.

Stock Trends – Inshore

For assessment purposes the inshore was divided into three areas: 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located; and 3) a southern area (southern 3L) that is largely dependent on migrant fish, from 3Ps and possibly other offshore areas. The dividing lines for these areas are Partridge Point at the western side of Notre Dame Bay and Grates Point at the eastern side of Trinity Bay (Fig. 3).

Commercial (Stewardship) Fishery

Catch and effort data for the <35 ft. sector, from log-books for the 2010 stewardship fishery, were examined and compared with those for 2006-09 (stewardship fishery) and 1998-2002 (index fishery). Median gillnet catch rates (kg/net) during 2010 were similar to or marginally lower than those observed in 2009. The trend in catch rates from log-books is generally consistent with sentinel survey information.

Sentinel surveys

Sentinel catch rates in the northern area did not increase in 2010 and were near the 1995-2010 northern area average (Fig. 12, upper panel). Catches in this area depend on seasonal immigration of fish from offshore regions, including 2J where offshore biomass remains low. Sentinel and commercial catch rates are lower in the northern area than those in the central area.

Sentinel catch rates in the central area did not increase in 2010 but remained above the 1995-2010 central area average (Fig. 12, middle panel). Catches in this area depend on resident inshore components and seasonal migrants from the offshore.

Sentinel catch rates in the southern area declined in 2010 and were below the 1995-2010 southern area average (Fig. 12, lower panel). Catches in this area are partly dependent on seasonal immigration of fish from the offshore of 3KL, and from 3Ps, where the stock has declined.

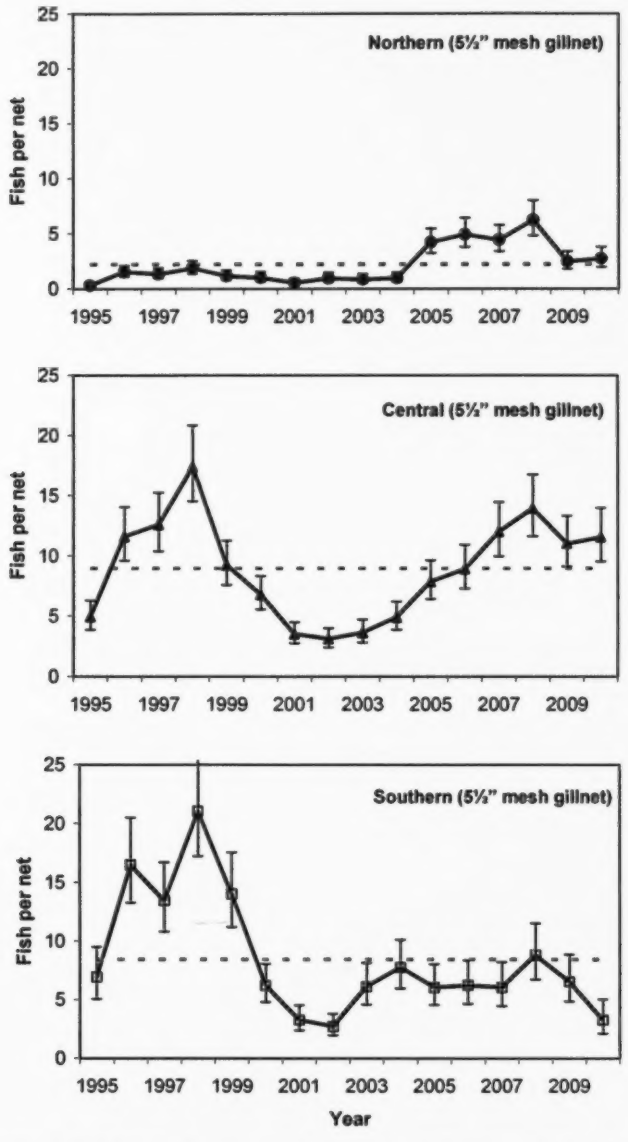

Figure 12: Standardized catch rates, with 95% confidence limits, from sentinel surveys using gillnets (5½ inch mesh) for each of the three inshore areas. Series means are plotted as dashed lines.

In the central area, catch-rate indices from line-trawls are currently close to the average of the time-series (Fig. 13). There are insufficient line-trawl data in the northern and southern areas to produce a standardized index time series.

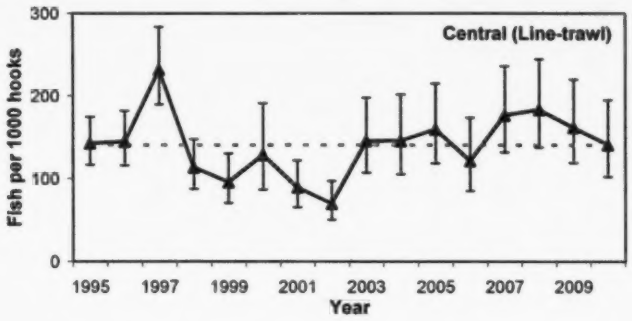

Figure 13: Standardized catch rates, with 95% confidence limits, from sentinel surveys using line-trawls for the inshore central area. Series mean is plotted as a dashed line.

Sentinel survey: Recruitment

An inshore recruitment index was derived from catch rates of juvenile cod during the sentinel survey (Fig. 14). The 1992, 2000, and 2002 year-classes are well above the average of 1992-2007. The four most recent year classes are estimated to be average (2004) or weaker than average (2005, 2006, 2007) and these are now contributing to the exploitable biomass.

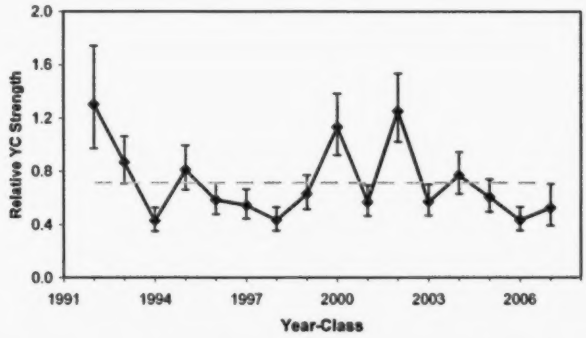

Figure 14: Standardized year class strength from sentinel survey catch rate data for ages 3 and 4 using 5½ inch and small mesh (3¼ inch) gillnets for the inshore central area. The dashed grey line is the time-series average.

Beach seine surveys: Pre-recruitment

Information on the strength of recent year-classes is available from a beach seine survey in Newman Sound, Bonavista Bay (northern 3L). This survey catches cod mainly of ages 0 and 1, with age 0 being much more strongly represented. These pre-recruit ages are not adequately represented in other indices. The information on age 1 from this study has been broadly consistent with the sentinel indices for the same year-classes at older ages. Several of the more recent year-classes (2003-06, 2008-09) are weak at age 1 and the 2005 year-class is the lowest in the time-series (Fig. 15); however, the 2007 year class at age 1 is close to the average for year-classes produced during 1995-2009.

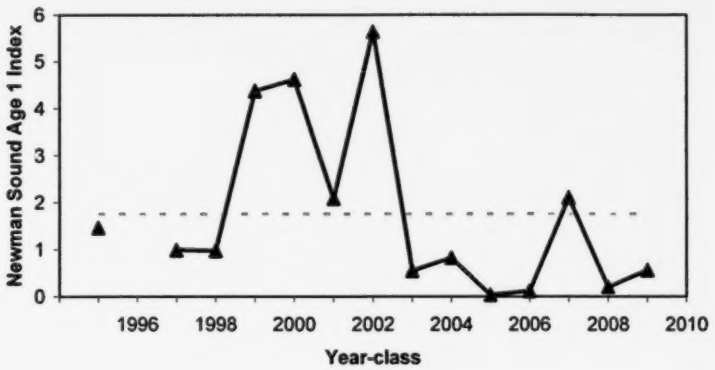

Figure 15: Trends in the numbers of age 1 cod from beach seine surveys in Newman Sound. Series mean is plotted as dashed line.

Numbers of age 0 cod caught at several sites in Newman Sound during 2010 surveys were lower than average. However, survival to age 1 can be highly variable; therefore, the strength of the 2010 year-class is currently uncertain.

Several sources of information (sentinel survey, year-class strength model, and beach seine survey) indicate that recent year-classes in the inshore have been poor relative to the 2000-02 year-classes. The lack of increase in sentinel and commercial catch rates in 2010 is consistent with the recruitment information from the inshore.

Hydroacoustic surveys

Winter hydroacoustic studies were conducted mostly during January-March in Smith Sound in western Trinity Bay (Fig. 3) starting in 1999. Biomass indices increased to a peak of about 26,000 t in 2001 and then declined to 18,000 t in 2004. The surveys were suspended in 2005 but resumed in 2006. Biomass indices were stable in 2006 at 16,500-18,500 t, but declined to 14,000 t in 2007 and to 7,200 t in 2008. The estimated biomass from surveys conducted in April 2009, June 2010 and February 2011 were much lower, i.e. 600 t, 300 t, and 449 t, respectively. These surveys were not all conducted at the same time of year and may not be directly comparable; acoustic telemetry has indicated that there is variable timing of migration out of Smith Sound during spring. Low exploitation rates from conventional tagging and high survival rates of acoustically tagged cod indicate that the lower biomass observed during 2009-11 is not solely due to the combined effects of fishing and natural mortality. The lower biomass more likely reflects a redistribution of some over-wintering cod from Smith Sound to other inshore areas or to the offshore.

DFO-Industry bottom-trawl survey

This survey was conducted in July-August during 2006-10 and covered nearshore areas from 15 m to 200 m depth. Catches have consistently been higher in the coastal strata (< 50 m depth in particular) and lowest in the northern area. This 5 year time series demonstrates high variability in terms of catch rates and age compositions, with the central and southern areas influenced by large catches (5-6 t/tow) in some strata. The 2007 and 2008 year classes are predominant in the 2010 survey catches. In addition, the abundance of ages 4-6 has diminished since 2008.

Results indicate that this survey may have potential as an indicator of recruitment at ages 1 and 2 in the inshore and nearshore; these ages are not well represented in the other surveys (sentinel and offshore).

Inshore tagging

Information from recaptures of cod tagged in various inshore regions of 3KL during 1997-2010 was used to estimate average annual exploitation (harvest) rates.

Exploitation rates were consistently low among central and southern areas, ranging between 3 and 10% during 2008-10. These estimates included a range of assumptions about the annual rate of natural mortality (0.2 - 0.4).

The reporting rate of tags from commercial fishers declined slightly during 2006-09 (57-64%), compared with previous years (1997-2005, 68-90%), indicating that fishers are becoming less inclined to return tags and recapture information. A constant but lower reporting rate of tags was estimated for recreational fishers during 2006-09 (46-50%). Lower reporting rates add uncertainty to the estimates of exploitation rates and the analyses of movement patterns and stock structure.

Biological Information (Inshore)

Changes in stock productivity as measured by growth and condition from sampling of sentinel gillnet catches are difficult to interpret. The catches may be comprised of fish from different areas and components of the stock.

Growth

Length-at-age and weight-at-age at ages 3 and 4 in 3K and 3L declined from the mid 2000s to 2009 but increased marginally in 2010. Length-at-age and weight-at-age among older cod show inconsistent trends and are more variable.

Condition

Condition of cod, measured using information on length and gutted weight, has shown a general decline since 2005 and values in 2009 and 2010 are among the lowest in the time series (1995-2010). Condition of cod, measured using information on length and liver weight, is consistently lower in Div 2J. Condition based on liver weight declined substantially in 3K and 3L from 2008 to 2009. Both measures of condition show marginal improvement in 2010.

Sources of Uncertainty

The harp seal population has been increasing for several years and is estimated to be approximately 9 million animals; some populations of cetaceans have also been increasing. Collectively marine mammals consume huge quantities of prey and have the potential to exert a strong influence on cod populations, both directly by predation on cod as well as indirectly by predation on key prey of cod, such as Capelin and shrimp. There is a high level of uncertainty surrounding the impact of marine mammal consumption on cod and overall ecosystem dynamics.

The relative proportion of inshore versus offshore cod that contribute to the inshore fishery catches is uncertain. However, the proportion of offshore cod is likely to have increased compared to the mid-1990s and early 2000s.

Estimates of stewardship fishery catch are uncertain. At stock assessment meetings and consultations commercial fishers often report that stewardship landings and recreational removals are underestimated. If the level is substantial, then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

There are no direct estimates of recreational landings for 2009 and 2010. Estimates of removals from recreational fisheries in other years are uncertain. Without accurate estimates of recreational catch, total catch for northern cod remains uncertain.

Some of the autumn RV surveys have extended well beyond their normal time and into the winter because of vessel problems. In addition, the survey was not fully completed in some years and coverage in some regions was sparse. These changes add uncertainty to survey estimates of mortality rates, abundance, and biomass.

There is uncertainty in the survival of fish caught in deep water (>300 m) offshore and released after tagging and implantation of acoustic tags. Ongoing research indicates that post-release mortality of cod trawled from deep water is variable but can be substantial.

INDUSTRY PERSPECTIVE

2010 2J3KL Stewardship Fishery

The stewardship fishery for cod (as prosecuted by commercial fish harvesters) is a limited entry fishery with gear restrictions (amount and type of gear), seasonal and duration restrictions, with landings being closely monitored at sea and at dockside. The data collected by commercial fish harvesters during this fishery is very important to the continued monitoring of the recovery of northern cod stock (inshore and offshore).

Fish harvesters feel that while the high catch rates during the late 1990's were largely driven by a narrow band of cod aggregations close to shore, much has changed in recent years. While current catch rates are about the same as those of the late 1990's, cod are much more widely distributed over inshore and offshore fishing grounds from very shallow depths to depths of 150 fathoms.

The DFO-Industry Inshore Mobile Survey now provides a 5 year time series. To date the data has not been thoroughly analyzed and as a result it has not been fully used in the assessment of the stock. Fish Harvesters feel that the survey is providing additional valuable science information and if we hope to gain a better understanding about the status of the Northern Cod Stock all available data must be fully utilized.

The uncertainty in the total landings, high-grading and discarding of small fish during the recreational cod fishery are all huge concerns for fish harvesters. Fish harvesters feel accurate landings information is imperative for the scientific assessment process.

2011 Telephone Survey of 2J3KL Fish Harvesters

2J3KL fish harvesters participated in the 2011 telephone questionnaire conducted by the FFAW from February 1 to February 10, 2011. The primary purpose of the telephone questionnaire was to collect observations of 2J3KL fish harvesters on the status of the Northern Cod Stock. Most 3K and 3L fish harvesters felt that cod were more abundant during 2010 than 1980's. Harvesters in 2J3KL felt cod abundance in 2010 comparable to the previous year, 2009. The majority of harvesters interviewed felt cod were distributed through out their area, and felt that the condition and health of cod were good. Most fish harvesters in all areas felt Capelin, mackerel and squid abundance were at low levels and declining.

CONCLUSIONS AND ADVICE

Total catch in 2010 and in other years is uncertain and there are no methods in place to quantify this uncertainty. A consistent time-series of accurate catch information is needed to evaluate the impact of fishery removals on the stock status. With accurate catch information additional methods of analysis would be available for science to investigate the population dynamics of the stock and provide advice to management.

A conservation LRP has been established for Northern cod. Estimated SSB has been well below the LRP since the early 1990s. The estimate of 2010 SSB is 90% below the LRP. At current levels of SSB the stock is considered to have suffered serious harm and the ability to produce good recruitment is seriously impaired. When the stock is at such a low level management actions should focus on promoting increases in SSB until the stock is more resilient to the effects of fishing. The application of the DFO fishery decision-making framework incorporating the precautionary approach would require catches in 2011 to be at the lowest possible level.

Overall, the results of this assessment are consistent with the results of the 2010 assessment. The lack of further increase in stock size is due to weaker age classes contributing to the SSB and an increase in total mortality rates. Current levels of removals have resulted in low exploitation rates and probably have had little impact on recent stock dynamics. At current levels of stock productivity (growth rates, recruitment, survival) the stock will not reach the LRP within the next five years.

OTHER CONSIDERATIONS

Management Issues

Recreational fishery

At current estimated levels of removals the recreational fishery is likely to be a substantial component of total removals. Improving the management of recreational fisheries is strongly recommended so that total removals can be effectively controlled and directly measured, and more accurate catch information provided to science to evaluate the impacts of fishing.

Ecosystem issues

Both shrimp and Capelin are important prey for cod; Capelin are at a low level and shrimp are declining. A combined low availability of two major forage species in the ecosystem could compromise the potential for recovery of cod in particular, and the groundfish community in general. These community-level implications need to be considered when harvesting is contemplated.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Regional Advisory Meeting of March 22-23rd, 2011 on the Stock Assessment of Northern (2J3KL) Cod. Additional publications from this process will be posted as they become available on the DFO Canadian Science Advisory Secretariat website at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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